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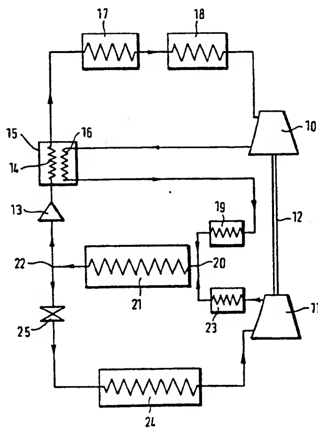
(54) Title: AIR CONDITIONING UNIT

(57) Abstract

An air conditioning unit includes a turbine driven compressor (10, 11) in which the turbine (10) is driven by means of a Rankin cycle in which a working fluid in liquid state is compressed and then vapourised by the application of heat to produce a high temperature high pressure vapour which drives the turbine (10); the compressor (11) driving a vapour compression refrigeration cycle in which a working fluid in its liquid state is vapourised by expansion to form a low temperature low pressure vapour; the two cycles being interconnected by a common condensor means (21) by which the vapour in both cycles is converted back into liquid.



AIR CONDITIONING UNIT

The present invention relates to an air conditioning unit, particularly though not exclusively an air conditioning unit for a motor vehicle.

Hitherto air conditioning units for motor vehicles have been based on a vapour compression refrigeration system including a compressor driven from the engine through electromagnetic clutch means. In a typical air conditioning unit, a refrigerant such as freon in its vapour state is compressed by an engine driven compressor and is passed through a condensor, where it is cooled by ambient air in order to convert it to its liquid state. The condensed freon is then forced through an expansion orifice, where it is converted back to its vapour state and cooled. The cool vapour then passes through a heat exchanger which cools air which is delivered to the vehicle. The freon vapour is then returned to the compressor. The air conditioning unit is controlled by sensors in the vehicle, which switch on and off an electromagnetic clutch, through which the compressor is driven.

With systems of this type, the compressor imposes significant loads on the engine which adversely effects the

fuel consumption and can also effect stability at idling speeds.

According to one aspect of the present invention an air conditioning unit includes a turbine driven compressor, in which the turbine is driven by means of a Rankin cycle in which a liquid is compressed and then vapourised by the application of heat to produce a high temperature high pressure vapour which drives the turbine; the compressor driving a vapour compression refrigeration cycle in which liquid is vapourised by expansion to form a low temperature low pressure vapour; the two cycles being interconnected by a common condensor means by which the vapour in both cycles in converted back into liquid.

According to a preferred embodiment of the invention the Rankin cycle comprises a liquid pump which serves to compress the liquid, the outlet from the pump being connected to the inlet of the turbine via a heat exchanger, where heat may be applied to the liquid to convert it into its vapour state. The vapour compression refrigeration cycle preferably comprises an expansion orifice through which the liquid is passed to convert it into its vapour state, the outlet side of the expansion orifice being connected to the inlet of the compressor via a heat exchanger which serves to cool air which passes over it.

The common condensor is preferably connected between the outlets of the turbine and compressor on its inlet side and between the pump and expansion orifice on its outlet side, so that it will liquify vapour coming from the turbine and the compressor.

This air conditioning unit is particularly suitable for use with motor vehicles where waste heat from the exhaust gases may be used to convert the liquid into vapour in the Rankin cycle. However heat from other sources, for example waste heat from other processes, fuel burners or electrical heating elements, may alternatively or additionally be used for this purpose.

As the fluid is pumped in its liquid state, a relatively small electric motor may be used for this purpose, this motor being driven by the conventional electrical generator of the vehicle. The turbine and hence refrigeration system may be controlled by switching on and off the electrically driven fluid pump, as required.

Unlike the engine driven compressor used hitherto, the relatively small electrically driven fluid pump will not place any significant load on the vehicle engine, with consequent advantage with regard to fuel consumption and stability at idling speeds. Furthermore, there is no need

for a belt drive or the like from the engine and electromagnetic clutch means which will significantly simplify installation of the air conditioning system. Also, as a common fluid is used throughout the system the turbine/compressor assembly is self contained and there is no need for a rotary fluid/air seal as required in engine driven compressor systems used hitherto.

An embodiment of the invention is now described, by way of example only, with reference to the accompanying drawing which shows in diagrammatic form, a refrigeration system for a motor vehicle air conditioning unit formed in accordance with the present invention.

As illustrated, the air conditioning unit comprises a turbine 10 which is drivingly interconnected to a centrifugal compressor 11 by means of shaft 12.

The output of an electrically driven pump 13 is connected via one channel 14 of a pre-heater 15, a boiler 17 and superheater 18 to the inlet of the turbine 10. The outlet from the turbine 10 is connected via a second channel 16 of the pre-heater 15 and a pre-cooler 19, to the inlet 20 of a condensor 21. The inlet to the pump 13 is connected to the outlet 22 of the condensor 21. The exhaust gases from the vehicle engine are used as the heat source for the boiler

17 and superheater 18, the exhaust gases being directed over the boiler and superheater tubes. Alternatively, a secondary source of heat, for example a fuel burner or electrical heating element, may be used to supply heat for the superheater 18.

The outlet from the compressor 11 is also connected to the inlet 20 of condensor 21 via a pre-cooler 23 and the inlet to the compressor 11 is connected via heat exchanger 24 and expansion orifice 25 to the outlet of the condensor 21.

The system described above defines a refrigeration circuit and compressor drive circuit which are interconnected by the common condensor 21. This dual circuit is charged with a suitable working fluid, such as Freon.

In operation, the working fluid, in its liquid state, is pumped by means of pump 13 through channel 14 of the pre-heater 15 to the boiler 17 and superheater 18, where the heat from the exhaust gases converts it into its vapour state. The relatively high temperature high pressure vapour then drives the turbine 10. Relatively hot vapour at reduced pressure leaving the turbine 10 passes through channel 16 of the pre-heater 15 to heat the fluid in its liquid state passing through channel 14. The hot vapour is then further cooled by pre-cooler 19 and then passes

through condensor 21, where ambient air cools it sufficiently to convert it back into its liquid state.

Working fluid in its liquid state is also forced through the expansion orifice 25 where it is converted into vapour at relatively low temperature and pressure. This low temperature vapour is passed through heat exchanger 24. Air is forced over the heat exchanger 24 by means of a blower (not shown) in order to cool the air before it is introduced into the vehicle. The low pressure vapour is then compressed by compressor 11, passed through pre-cooler 23 to remove some of the heat generated during compression and then through the condensor 21, where it is again converted back into a liquid state.

The above system may be controlled in response to temperature sensors in the vehicle, switching the system on and off as required. This may be achieved by switching the electrically driven pump 13, on or off. Alternatively, the turbine drive may be shut off by stopping the supply of exhaust gases to the boiler 17 and superheater 18. This may, for example, be done by means of a gate valve in the exhaust gas supply line.

In addition to sensors in the vehicle, further sensors may be included in the system itself to control operating

conditions. For example a thermal switch may be provided at the outlet 22 of the condensor 21 to switch off pump 13 or divert the supply of exhaust gas away from the boiler 17 and superheater 18, if the temperature at the outlet 22 falls below a critical value.

When the system is in operation, the pump 13 will be driven at a fixed speed and the system will normally operate under steady state conditions. For a typical system as described above, under these steady state conditions, the working fluid at the inlet to the pump 13 and expansion orifice 25 will be liquid and at a temperature of 60°C and a pressure of 310 kN/m^2. The pump 13 will increase the pressure of the fluid to 1930 kN/m^2 and temperature to 140°C. The liquid remains at this pressure as it is passed through the pre-heater 15, its temperature being increased to 145°C. On passing through the boiler 17 and superheater 18, the liquid is converted to vapour at a pressure of 1930 kN/m^2 and temperature of 250°C which then drives the turbine 10. On exiting from the turbine 10, the pressure of the vapour is reduced to 310 kN/m^2 at a temperature of 190°C. The vapour at this pressure is then further cooled to 75°C by the pre-heater 15 and 60°C by the pre-cooler 19. The vapour at 60°C and 310 kN/m^2 is then converted back to liquid at the same temperature and pressure, on passing through the condensor 21. The passage of the liquid

through the expansion orifice, reduces the pressure to 50 kN/m^2 and temperature to 5°C, the temperature subsequently being increased to 15°C on passage through heat exchanger 24. The compressor then compresses the vapour to a pressure of 310 kN/m^2 at a temperature of 120°C which is subsequently cooled to 60°C on passage through pre-cooler 23. Again, this vapour at 60°C and 310 kN/m^2 is converted back to liquid at the same temperature and pressure by means of the condensor 21.

The above system is self-regulating, for example if initially the turbine 10 does not drive the compressor 11 at a sufficient speed, so that the pressure at the outlet of the compressor 11 is low, the pressure at the outlet of the turbine will be reduced correspondingly, thus increasing the pressure differential across the turbine 10 and causing it to speed up. Similarly, if the compressor 11 is too fast, its outlet pressure will be above the steady state condition, but the pressure differential across the turbine 10 will be reduced, thus slowing the turbine 10.

Fluid in its vapour or liquid state may be tapped off at some point between the outlet of pump 13 and the boiler 17 and fed to the bearings of the turbine 10/compressor 11 for lubrication and cooling purposes. This fluid may then be

returned to the inlet of the pump 13 by separate line or may be allowed to leak into the turbine 10 or compressor 11 and back to the pump 13 via the condensor 21.

Various modifications may be made without departing from the invention. For example, the pre-heater 15 may be omitted from the compressor drive circuit. Also, the pump 13 may be driven by other than electrical means. For example it may be driven from the engine. As the pump 13 pumps the fluid in its liquid state rather than its vapour state, its capacity is relatively small as compared to the capacity of the engine driven compressor of a conventional system, consequently even if the pump 13 is driven by the engine, the power requirement is very much reduced and consequently will still provide advantages with respect to fuel consumption and engine idle speed stability, also some form of clutch mechanism will be required if the pump is to be switched on and off. Further elements conventionally used in refrigeration circuits, for example a filter provided on the inlet side of the expansion orifice and a drier/oil separator at the inlet to the compressor may also be included in the system covered by the present invention.

CLAIMS

1. An air conditioning unit characterised in that a compressor (11) is driven by a turbine (10) the turbine (10) being driven by means of a Rankin cycle in which a working fluid in liquid state is compressed and then vapourised by the application of heat to produce a high temperature high pressure vapour which drives the turbine (10); the compressor (11) driving a vapour compression refrigeration cycle in which a working fluid in liquid state is vapourised by expansion to form a low temperature low pressure vapour; the two cycles being interconnected by a common condensor means (21), by which the vapour in both cycles is converted back into liquid.

2. An air conditioning unit according to claim 1 characterised in that the turbine (10) and compressor (11) are connected in different fluid circuits, these circuits being interconnected by the common condensor (21).

3. An air conditioning unit according to claim 2 characterised in that a pump (13) is connected to the outlet (22) of the condensor (21), the outlet from the pump (13) being connected via a heat exchanger (18, 19) to the inlet of the turbine (10) and the outlet of the turbine (10) being connected to the inlet (20) to the condensor

(21), means being provided by which heat may be applied to the working fluid as it passes through the heat exchanger (17, 18), to convert the working fluid from its liquid to its vapour state.

4. An air conditioning unit according to claim 3 characterised in that the heat exchanger (17, 18) comprises a boiler unit (17) and a super heater unit (18).

5. An air conditioning unit according to claim 4 characterised in that the boiler and super heater units (17, 18) are heated by means of exhaust gases from a motor vehicle.

6. An air conditioning unit according to claim 4 characterised in that the super heater unit (18) is heated by a fuel burner or electrical heating element.

7. An air conditioning unit according to any one of claims 3 to 6 characterised in that a pre-heater (15) is included between the pump (13) and the heat exchanger (17, 18), by means of which heat may be transferred to the liquid compressed by the pump (13) from the vapour leaving the turbine (10).

8. An air conditioning unit according to any one of

claims 2 to 7 characterised in that an expansion orifice (25) is connected to the outlet (22) of the condensor (21), the outlet of the expansion orifice (25) being connected to the inlet of the compressor (11) via a heat exchanger (24), the outlet from the compressor (11) being connected to the inlet (20) of the condensor (21).

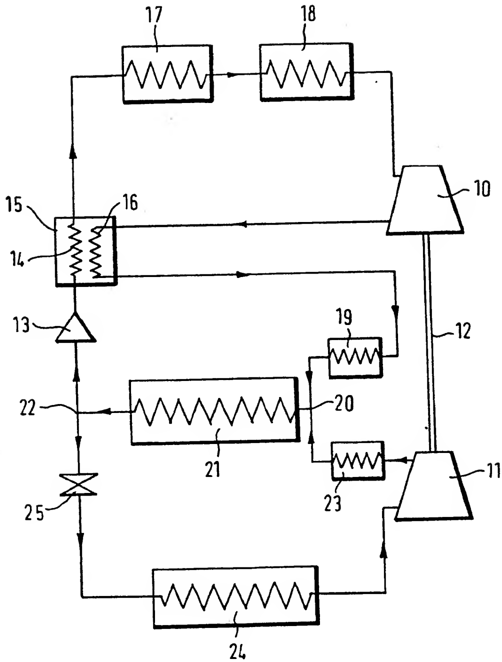
9. An air conditioning unit according to any one of claims 2 to 8 characterised in that means (19, 23) is provided between the outlet of the turbine (10) and the inlet (20) of the condensor (21) and/or between the outlet of the compressor (11) and the inlet (20) of the condensor (21), for balancing the temperature of the vapour in the two circuits which is delivered to the inlet (20) of the condensor (21).

10. An air conditioning unit according to any of the preceding claims characterised in that internal and/or external sensors are used to control the pressure of vapour delivered to the inlet of the turbine (10) in order to switch on or switch off the refrigeration cycle as required.

11. An air conditioning unit according to claim 10 characterised in that the pressure of vapour delivered to the turbine (10) is controlled by switching the pump (13)

on or off as desired.

12. An air conditioning unit according to claim 10 characterised in that the pressure of the vapour delivered to the turbine (10) is controlled by controlling delivery of heat to the heat exchanger (17, 18).



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INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 87/00398

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^4: F 25 B 11/00

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^4	F 25 B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	US, A, 2305162 (HOLMES) 15 December 1942 see the whole document --	1-12
X	DE, A, 2417158 (ALEX. FRIEDMANN KG) 14 November 1974 see the whole document --	1-4,6,8
A	US, A, 2411347 (TRUMPLER) 19 November 1946 --	
A	DE, A, 1932748 (LINDE AG) 7 January 1971 --	
A	US, A, 3728857 (NICHOLS) 24 April 1973	

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* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
28th August 1987	25 SEP 1987
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	L. ROSSI

Form PCT/ISA/210 (second sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/GB 87/00398 (SA 17433)

This Annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 09/09/87

The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A- 2305162		None		
DE-A- 2417158	14/11/74	AT-A,B	321351	25/03/75
US-A- 2411347		None		
DE-A- 1932748	07/01/71	NL-A-	7009463	29/12/70
		FR-A-	2051403	02/04/71
		BE-A-	751794	16/11/70
US-A- 3728857	24/04/73	None		

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82